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ABSTRACT

To address the need to develop a scientifically literate citizenry, the socio-scientific reasoning model was created to guide curriculum development. Goals of this developmental approach include increasing: (1) students' skills in dealing with problems containing multiple interacting variables; (2) students' decision-making skills incorporating a wide social perspective; and (3) critical thinking skills in the evaluation of consequences and implications of decisions. Secondary school students (grades 7-12, from both public and private sectors) enrolled in courses in chemistry, earth science, biology, health, social sciences, and physics are currently participating in the field test and evaluation of these curriculum materials. Tests designed to evaluate knowledge, critical thinking, and moral/ethical reasoning have been administered to approximately 1,000 students. The experimental design for the field test is the non-equivalent comparison group design where experimental and control groups are pre-tested and post-tested. Mean scores of the experimental and control groups are compared using a t-test to determine if the experimental group achieved significant improvement in the cognitive and affective domains. Preliminary analysis of the data indicate that these curricula materials have the potential to affect development in both the cognitive and affective domains. (Author/BB)

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AN EVALUATION OF CURRICULUM MATERIALS BASED UPON THE SOCIO-SCIENTIFIC REASONING MODEL

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With the continuing complexity of issues facing society, we can no longer confine our curriculum studies to the boundaries of traditional disciplines. As Piaget has argued in his work, To Understand is to Invent, more effective solutions to our societal problems will emerge from interdisciplinary research (Piaget, 1973).

The Institute for Science, Technology and Social Science Education at Rutgers - The State University, has addressed this issue directly. Combining the theoretical positions of Piaget, Kohlberg and Dewey, the Institute has formulated what we call the Socio-Scientific Reasoning Model. The model seeks to foster increased growth in these areas: cognitive skills, critical thinking, decision-making, problem solving, and moral/ethical reasoning. To achieve these overall objectives, the Institute has developed fourteen self-contained modules; each interdisciplinary and flexible; each designed to supplement existing curricula. The common thread linking the modules is the concept that issues interfacing science, technology and society have significant ramifications in all areas and at all levels--international, national and personal. Moreover, they raise important moral/ethical considerations.

The factual information on each issue is provided through readings and classroom activities or drawn from the students' own research and experiences. Through interaction with the issues, and discussion with their classmates, students choose, evaluate and defend courses of action to resolve dilemma situations. In the process of encountering new viewpoints, students examine their own judgments and positions from a more enlightened perspective.

The fourteen modules are designed within the framework of traditional disciplines but extended to incorporate ideas and concepts from other disciplines so that their multiple interactions are highlighted. Moreover, the

implications of new developments and their applications are examined from the perspective of possible societal impacts and responses. Hypothetical dilemmas or dilemmas drawn from real case histories are employed to heighten the issues and stimulate discourse. Among some of the issues addressed are use of natural resources, allocation of scarce resources, the wisdom of applying certain new technologies and the effects of various activities on the natural environment and man.

The target group of these modules is the broad range of students in secondary schools, grades 7 through 12. Research has shown that this age group is most likely to profit from increased exposure to different strategies of learning (Lawson, Nordland and Blake, 1977; Kuhn, 1978; Lockwood, 1978).

Table 1 lists five of these modules and their suggested grade levels and subject area within which the module might be most appropriate. However, this is but a small range of possibilities as grade level and subject area are best determined by the teacher who understands the interest and needs of his/her students. The final column highlights some of the major foci of each module (see Table 1).

Table 2 summarizes the curriculum strategies employed in the modules to promote development as previously discussed. They represent some of the possible educational strategies and techniques the Institute has identified to be useful in increasing skills in moral/ethical reasoning, critical thinking and problem solving. On the upper part of the chart are listed strategies unique to certain modules, such as developing role perspectives. The lower part of the chart depicts goals toward which the small and large group discussions, an integral part of all units, are directed. These goals specify what is meant by moral/ethical reasoning and critical thinking.

TABLE 1. INTERDISCIPLINARY CURRICULUM MODULES

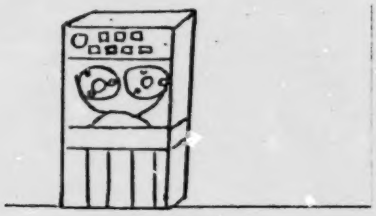
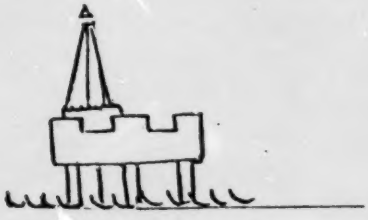
TITLE	GRADE LEVEL/ SUBJECT	CONTENT
ENERGY DECISIONS	7,8/ SOCIAL STUDIES GENERAL SCIENCE	EXPLORES ISSUES OF CONSUMPTION, PRODUCTION AND CONSERVATION OF ENERGY. THREE SOURCES; PETROLEUM, NUCLEAR POWER AND COAL.
FUTURE COMMUNICATIONS 	7,8/ SOCIAL STUDIES LANGUAGE ARTS	COMPARES THE DEVELOPMENT OF TWO COMMUNICATION SYSTEMS, PAST AND FUTURE. EMPHASIZES THE IMPACT OF CHANGE WITH FUTURE FORECASTING.
DILEMMAS IN BIOETHICS	11,12/ HEALTH BIOLOGY	EXPLORES 12 CASE STUDIES IN BIOLOGY AND MEDICINE. RAISES SOCIAL AND LEGAL ISSUES; ORGAN TRANSPLANTS, GENETIC RESEARCH, GENETIC SCREEING.
ENVIRONMENTAL DILEMMAS 	10,11/ GENERAL SCIENCE ENVIRONMENTAL SCIENCE	EMPHASIZES TECHNICAL AND SOCIAL ASPECTS OF ENVIRONMENTAL PROBLEMS. 12 CASE STUDIES; RADIATION HAZARDS, TOXIC CHEMICALS, NATURAL RESOURCE MANAGEMENT.
BEACON CITY	11,12/ URBAN STUDIES	SIMULATION SET IN URBAN COASTAL TOWN. EXAMINES SOCIAL, ECONOMIC AND POLITICAL FACTORS FOR OPTIMAL USE OF A LAND PARCEL.

TABLE 2. CURRICULUM STRATEGIES AND STUDENT ACTIVITIES

ENERGY DECISIONS	- DILEMMA DISCUSSION
BIOETHICS	- ROLE PLAYING
ENVIRONMENTAL DILEMMAS	- CRITICAL READING AND ANALYSIS
FUTURE COMMUNICATIONS	FUTURE FORECASTING: - SCENARIO WRITING - DELPHI PROBE
BEACON CITY	- DEVELOP ROLE PERSPECTIVES - PREPARE PROPOSAL - DEBATE AND NEGOTIATE

ALL MODULES: SMALL AND LARGE GROUP DISCUSSIONS ALLOW STUDENTS TO:

1. REASON HYPOTHETICALLY
2. GENERATE POSSIBLE ALTERNATIVES
3. CONSIDER CONSEQUENCES OF ALTERNATIVES
4. INTEGRATE PERSONAL EXPERIENCE INTO SOCIAL WHOLES
5. REFLECT ON OWN THINKING, CONSIDER PERSPECTIVES OF OTHERS
6. CRITICALLY USE INFORMATION SOURCES
7. EXPLORE DIFFERENT PROBLEM SOLVING STRATEGIES

Evaluation

A preliminary field test, testing the first five modules developed, was conducted during the 1977-78 school year, to determine the adequacy of the evaluation design and the potential student behavioral changes resulting from exposure to the materials, and strategies employed. The design, instrumentation and results, are summarized below.

Design:

Table 3 depicts the outline of the evaluation design which is characterized as a non-equivalent comparison group. That is, the experimental groups are larger in size than the control group. The design includes four dependent variables: 1) level of moral/ethical reasoning, 2) degree of critical thinking, 3) factual knowledge and 4) verbal aptitude.

Both project groups (experimental) and comparison groups received pre- and post-tests. Sex and treatment group served as independent variables.

Instruments:

To determine change in moral/ethical reasoning, Rest's DIT and Iozzi's EIT were employed. One or the other test or a combination of both was administered depending on the particular topic area addressed by the module.

The variable of critical thinking was measured pre and post with the Cornell Critical Thinking Test, Level X: Exploring in Nicoma.

Factual knowledge about topics addressed in the modules was measured with knowledge tests designed by the project staff expressly for each module. These tests were validated by a panel of specialists knowledgeable in that subject area.

Finally, to control for the role of verbal ability and aptitude as a

TABLE 3. EXPERIMENTAL DESIGN FIELD TEST 77-78

- NON EQUIVALENT COMPARISON GROUPS -

DEPENDENT VARIABLES	INSTRUMENTS
MORAL/ETHICAL REASONING	- DEFINING ISSUES TEST (REST, 1974) PRE/POST - ENVIRONMENTAL ISSUES TEST (IOZZI, 1978) PRE/POST
CRITICAL THINKING DECISION MAKING PROBLEM SOLVING	- CORNELL CRITICAL THINKING TEST (ENNIS, 1971) PRE/POST
FACTUAL KNOWLEDGE	- PROJECT DEVELOPED TESTS PRE/POST
APTITUDE/ABILITY	- SCHOOL AND COLLEGE ABILITY TEST, SERIES I VERBAL (ETS, 1973) FORM 3A - 7,8; FORM 2A - 9-12 (PRE TEST ONLY)

INDEPENDENT VARIALBES: SEX, TREATMENT

POPULATION:	DURATION:
20 SCHOOLS	2-6 WEEKS INTERVENTION
30 TEACHERS	TIME: FEB - JUNE 1978
2000 STUDENTS	

function of learning change, the SCAT test, Verbal Series II, Forms 2 or 3A, were administered prior to the intervention.

This evaluation design required administering a total of seven tests (4 tests) prior to beginning the module and three post tests following completion of the module.

Some general characteristics of the subject population follow. The student population of over 2,000 was drawn from more than 20 schools throughout the state of New Jersey. Rural, suburban and urban schools were included. Over 30 teachers participated in this preliminary field test. The project classrooms represented a broad mix of social studies, language arts and science classes.

The field testing, which covered a four-month period from February to June, had a dual purpose. Analysis included tests of the variance effects on the independent variables and intervation effects on each of the three dependent variables: critical thinking (decision-making, problem solving), moral/ethical reasoning and knowledge about the issues. Differences would be considered significant if they achieve the .05 level of statistical significance.

The results with the modules varied. The field test 1977-78 ran from February through June and served two very broad goals: firstly, identification of general strengths and weaknesses of the evaluation procedures. Specifically, the Institute was concerned with the following:

1) measurement design
2) development of an appropriate statistical analysis program
3) instrumentation - how appropriate were these instruments in making judgments about the intervention
4) administrative and recording procedures

5) teacher training program

6) teacher and student responses to the modules under actual field test conditions.

This was basically a field test of the field test design. In addition, it would provide data regarding the effectiveness of material content and strategies employed.

Results:

Regarding the latter aim of the field test, that is, the effectiveness of the modules, the overall results were most encouraging, especially in view of the obstacles encountered in meeting all the requirements of the design. Gains were found between pre and post test scores of at least 2 out of 3 of the dependent variables for each of the five modules tested. The dominant gains were found with factual knowledge and moral reasoning.

The following table (Table 4) shows some specific results achieved by one teacher who used the module early in the semester, employing all the techniques specified in the manual, completing all the activities in the module, and administering all pre and post tests to both experimental and control groups.

The measures of knowledge and critical thinking showed gains significant at $p < .001$. However, there was no significant gain in moral/ethical reasoning. We attribute this finding to the specific focus of the unit on futures forecasting techniques. In this particular module moral/ethical reasoning issues were treated only peripherally.

Table 5 shows the composite results of this preliminary field test. The generalizability of these results was somewhat limited since comparison groups with sufficient data were lacking for Beacon City and Energy on two of the three variables being considered.

TABLE 4. FIELD TEST RESULTS: FUTURE COMMUNICATIONS MODULE

KNOWLEDGE

	N	PRE	POST	DIFF	I	SIG
EXP.	(90)	38.95	52.04	13.09	8.703	.001
CONTROL	(24)	41.74	44.45	2.71	1.238	NS

CRITICAL THINKING

EXP.	(90)	45.94	49.61	3.67	3.592	.001
CONTROL	(24)	49.49	50.39	.09	1.413	NS

ETHICAL REASONING

EXP.	(90)	21.67	22.77	1.10	.469	NS
CONTROL	(24)	21.71	24.44	2.71	1.364	NS

SCAT (ABILITY)

$\bar{X}$ EXP.	$\bar{X}$ CONTROL	DIFF.	T	SIG
26.67	27.25	.58	.319	NS

TABLE 5. OVERALL FIELD TEST RESULTS 1977-78

MODULE	KNOWLEDGE	CRITICAL THINKING	MORAL/ETHICAL REASONING
BEACON CITY: A LAND USE SIMULATION[1*]	X		X
BIOETHICS, DILEMMAS IN	X	IND	X
ENVIRONMENTAL DILEMMAS: CRITICAL DECISIONS FOR SOCIETY	X	IND	X
ENERGY: DECISIONS FOR TODAY AND TOMORROW[1]		X	X
FUTURE SCENARIOS IN COMMUNICATIONS	X	X	N.A.

(* - FIELD TEST DURATION - 2 WEEKS)

X - PRE-POST TEST DIFFERENCE SIGNIFICANT AT .05 LEVEL OR HIGHER

1 - TOTAL SAMPLE LACKED COMPARISON GROUP

Both factual knowledge and level of moral reasoning increased between pre and post tests for the majority of the modules. Gains in the level of moral reasoning were especially encouraging. We expected knowledge gains since this area is one most teachers achieve with ease. On the other hand, teaching for gains in critical thinking may lie in the sensitivity of currently workable measures for that capability. However, our results in moral reasoning change were in agreement of the general trends characteristic of research in moral reasoning. In Lockwood's recent summary (Lockwood, 1978) students of the same age as our students achieved gains in level of moral reasoning from Stage 2 to Stage 4 through methods of direct discussion which paralleled our group dilemma discussions.

Discussion

These preliminary field test results point to certain methodological problems and provide suggestions for future changes:

1) The 1977-78 test design requires 7 tests per student (a total of 14,000 tests were administered). This is a substantial burden on teachers and few are able to devote seven classroom periods strictly to testing, given that the intervention extends over about four weeks. To resolve these time problems, the 1978-79 design will require each student to take only one pre-test, one SCAT test, and one post-test. The distribution of the tests will alternate so that 1/3 of the class takes the critical thinking test pre and post, 1/3 takes the knowledge test pre and post and 1/3 takes the moral reasoning test pre and post.

2) The time of the year in which the field test is conducted will be

more regorously monitored so that adequate post testing is assured despite numerous distractions at the end of the school year. Half the data collected has been discarded because those students did not complete all of the seven tests required. The contrast in achievement gains with Bioethics compared to achievement gains with Environmental Dilemmas speaks to this issue. Despite the similarity of techniques and format, these units produce widely different gains. This can be attributed to the fact that Bioethics was field tested early in the semester while Environmental Dilemmas was field tested later in the year and students were taking post tests on the last day of school. Absenteeism is high at this time of the year.

3) Restraints imposed by school activities and curriculum demands also prevented many teachers from completing the modules as prescribed.

4a) With regard to the appropriateness of the instrument used; results of the knowledge test in the Energy module show that students are more sophisticated about energy concerns than had been anticipated. Given the very high scores obtained, it is not possible to detect growth changes. Thus, this particular factual knowledge test has been upgraded.

4b) The Cornell Critical Thinking Test as it was previously scored may not be the most sensitive instrument for a pre-test/post-test intervention design. There is a possibility that since students remember the end of the story from the pre test, their responses to the post test are unduly influenced by this knowledge. Furthermore, certain scales of the Cornell test measure skills which are

not emphasized in the modules; it is possible that subscale scores would be more appropriate. This year the tests will be scored for composite and subscale data to cover this eventuality.

5) Teacher training workshops include an introduction to the philosophy and theoretical basis of the program, the techniques and strategies employed, and specific guidance in the use of a particular module. The training period is one or two days, depending on the size of the group and the needs of the teachers. The major emphasis of previous workshops has been on the strategies for conducting dilemma discussions, but in light of the indeterminate results obtained on critical thinking, teaching techniques to promote critical thinking will be emphasized. This skill may not be common to all in-service teachers.

6) Testing in 1978-79 will be more rigorously delineated and include sufficient numbers of comparable grade level control groups. Definitive conclusions cannot be drawn from much of the data because several of the school grade levels of the control and test group are not comparable. In the current field test we are seeking a minimum of 180 students in both experimental and control groups. Each module will be tested with two grade levels instead of the wider grade span covered in the first field test.

With the improved standardization procedures and the encouragement of qualified results from preliminary 1977-78 field test, it is anticipated that the 14 modules to be tested will be shown to stimulate statistically significant improvement in students' level of moral/ethical reasoning, and level of critical thinking as measured by standardized tests. At the same time they will be acquiring knowledge about, and strategies for, the understanding of critical issues which stand at the interface of science and society.

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